Long Term Goal 2: Provide the tools to assess and diagnose the causes and pollutant sources of impairment in aquatic systems

Introduction

Once a water body is monitored and the condition is assessed (LTG1), the waterbody may be identified and listed as "impaired" under CWA Section 305b. For some stressors (e.g., toxics, pesticides), the cause and sources of the impairment may be relatively easy to identify (with the exception of major water bodies with numerous stressor sources). For the majority of stressors (e.g., nutrients, suspended sediments, pathogens, toxics in major water bodies with multiple sources) the cause of the impairment is known (because of the direct relationship to the stressor-specific criteria), but the relative contributions from different sources is uncertain. EPA is encouraging states and tribes to adopt biological criteria and assessments as a more effective measure of water body condition (compared to physical/chemical measurements and criteria). In this case, unlike stressor-specific criteria, both the causes and the sources of biological impairment are difficult to identify. Long Term Goal 2 addresses all of these "diagnostic" needs. To improve overall efficiency of the TMDL process and to coordinate remediation activities, diagnosis of the cause of impairment is needed not only at the scale of individual water bodies, but also at the watershed scale. Scientifically defensible diagnostic methods are needed to develop and justify restoration plans that aim to reduce stressor loadings from both point and non-point sources (e.g., TMDL allocations). The development and evaluation of restoration options is addressed in Long Term Goal 3.

Research Framework

In developing the research framework for the WQ MYP, ORD considered and evaluated the States' implementation stages from applying criteria and monitoring condition (LTG1) through diagnosing causes and sources of impairment (LTG2) to evaluating and implementing protection and restoration alternatives (LTG3). Under LTG2 diagnostics research, all the major stressors responsible for commonly reported designated use impairments (habitat alteration, nutrients, suspended and bedded sediments, pathogens and toxic chemicals) are considered. The starting point for diagnostic research is the need to respond to reports of water quality impairments, nonattainment of designated uses, and other indications of adverse effects (e.g., toxicity). Initial monitoring and condition assessments may provide evidence of multiple potential causes of impairment and conflicting lines of evidence that might complicate a diagnosis. Thus, the endpoint for the diagnostic process includes both the definition of the primary cause(s) and/or source(s) of impairment as well as the allocation of observed effects among multiple potential stressors, and the assessment of potential interactive effects among stressors. An array of data and tools are investigated for diagnostic approaches, including water body and ecosystem classification schemes, landscape characterization, cause-effect modeling and experimental watershed analysis methods including gradient studies. Outputs from diagnostics research are incorporated into decision-support systems for use by clients (i.e., Stressor Identification Guidance, CADDIS). The following scientific questions and research has evolved from this MYP framework.

- How can multiple and possibly related causes of biological impairment be inferred from indicator and other observations, and cause-effect modeling ? For habitat alteration? For nutrients? For suspended and bedded sediments? For pathogens? For toxic chemicals?

ORD and OW staff collaborated to develop a logical, scientific process to evaluate available information for identifying the stressors that are most likely causing biological impairments by synthesizing approaches from different intellectual fields into a defensible and useful methodology that identifies the probable cause or causes of undesirable biological conditions (i.e., the Stressor Identification Guidance Document – **Poster LTG2-1**). The Stressor Identification Guidance Document has provided a foundation for advancing the field of causal analysis. It is being adapted for application in estuaries and terrestrial systems, including studies outside the U.S. Examples, analytical tools, and a step-by-step guide to the method are being developed as part of the Causal Analysis/Diagnosis Decision Information System (CADDIS). CADDIS **(Poster LTG2-2)** is a web-based decision support system that will help scientists in the regions, states and tribes find, access, use, and share information to determine the causes of biological impairments in aquatic systems, and will help scientists make causal determinations more quickly, cheaply and defensibly. With regard to specific stressors such as nutrients, EPA ORD participates in the Ecology and Oceanography of Harmful Algal Blooms (EcoHAB) program through its Science to Achieve Results (STAR) grants program – the research enhances the development of ecological risk assessments for nutrients, as well as the development of stressor-response models aimed at understanding and predicting the relationship between stressors such as nutrients, eutrophication, and hypoxia on aquatic ecosystems **(Poster LTG2-4)**. To address pathogens stressors, EPA ORD has provided microbial source tracking (MST) tools, conducted workshops and has developed the MST Guide Document for discriminating between sources of fecal pollution in watersheds. With these tools water resource managers can evaluate best management practices and implement efficient pollution prevention measures aimed at reducing the levels of contamination of source water, i.e., water ultimately used for human recreation or consumption **(Poster LTG2-5).** To address toxins such as EDCs and pesticides as stressors, novel diagnostic research using the combination of molecular and whole organism endpoints will allow us to identify and compare dose- and time-dependent indicators across multiple biological and taxonomic levels. This research also allows us to enhance linkages from stressor sources to effects, i.e., database of benthic macroinvertebrate and algal taxa in a region of heavy pesticide usage, develop methods for quantifying species preferences from large, field-collected data sets, and develop EDC- and pesticide-induced molecular diagnostic exposure markers **(Poster LTG2-6).** To address multiple stressors, ORD is conducting source tracking and other research on the potential for Concentrated Animal Feeding Operations (CAFOs) to contribute nutrients, pathogens, EDCs, and other stressors to ground water, and how will they ultimately impact surface water quality **(Poster LTG2-7).**

- How can the sources and source strengths of stressors be inferred from *in situ* measurements? From stressor measurements? From biological indicators? From remotely-sensed observations and watershed properties?

To develop diagnostic tools and approaches for estuarine watersheds, case studies were conducted for two estuarine sites **(Poster LTG2-8)**. Laboratory and field measures and tools are being developed to diagnose excess nutrients, elevated levels of toxic chemicals, anomalous suspended and bedded sediments (SABS), and adverse habitat alteration, i.e., . A normalization procedure using sediment grain size and total organic carbon (TOC) is being evaluated as an indicator of nutrient enrichment and anomalous suspended and bedded sediments (SABS); Toxicity Identification Evaluation (TIE) methods are being developed for solid phase sediments. In addition, diagnostic community-level indicators are being identified that are specific to nutrient impairments, methods for differentiating the impact of natural versus anthropogenic stress on estuarine benthic communities are being investigated and remote sensing is being applied for detecting benthic community impairments (**Poster LTG2-9)**.

- How does one determine the most appropriate and efficient scale for application of diagnostic methods within the TMDL and 303(d) process?

Diagnostic conceptual models and methods for understanding mechanisms of stressor action and interactions, differences in the response of aquatic ecosystems to stress, and the effectiveness of controlling pollutant loads at different spatial and temporal scales are being developed **(Poster LTG2-3)** to provide a simple and powerful approach to identifying the cause of impairment in freshwater, estuarine and marine ecosystems. A hydrology-based watershed classification scheme that can predict the sensitivity of water bodies to nonpoint source pollution is being developed for linking condition and diagnostic assessments and for extrapolating results to similar watersheds **(PosterLTG2-10).** In addition, an estuarine classification has been developed that groups US estuaries based on existing physical and hydrological data, properties that may influence their susceptibility to increased nutrient loading, increased toxic inputs, altered sediment loading, or changes in habitat characteristics **(Poster LTG2-11).**

Future Research

Future research will continue to focus on developing better (faster, less expensive, more accurate) ways to identify causes and sources of water body impairments. This research will continue to cover a wide temporal and spatial scale, ranging from rapid and specific molecular detection (for pathogens) to classification schemes and landscape models for extrapolation at watershed scales. Many of these results will be synthesized and transferred to users through CADDIS **(Poster LTG2-2)** and other web-accessible decision support toolboxes. Detailed energy systems models showing causal webs of interaction for nutrients, suspended and bedded sediments, toxic chemicals and habitat alteration **(Poster LTG2-3)** will be refined, evaluated, and simulated to provide predictive models of the effects of multiple stressors on aquatic ecosystems, and the development of a stressor-based classification system using the generic conceptual models as a guide is also planned for the future. For pathogens, future effort will focus on developing methods that can simultaneously monitor multiple indicator species, source tracking markers, and pathogens in source waters, as well as provide training support **(Poster LTG2-5)**. Novel diagnostic indicators for a variety of stressors will be further

developed and evaluated to determine the relevance and linkage of biological data generated from multiple biological and taxonomic levels **(Poster LTG2-6).** ORD plans to continue monitoring ground water quality at CAFO sites to assess the long-term impact on ground and surface water quality, and will evaluate additional types of CAFOs to more completely determine the potential for ground water impact. The near-term focus will be on Comprehensive Nutrient Management Plans (CNMP) effectiveness and nitrate source tracking, but additional research issues will be targeted based on continued collaborations with USDA and other agencies **(Poster LTG2-7).** For diagnosing estuarine systems, analyses are planned to assess sites with anomalous grain size-TOC values to evaluate the potential for diagnosing impairments caused by suspended and bedded sediments, diagnostic tools needed by the States and Regions **(Poster LTG2-8).** . Further refinement and meta-analysis of the historical database for EPA Region 5 streams and rivers for community-level indicators of nutrient impairment is planned, with queries to derive indicators incorporated into a MS Access database structure for state and regional use. In addition, new benthic and fish community metrics compiled from R-EMAP, EMAP, and National Coastal Assessment databases will be used to derive and evaluate community-level indicators for estuaries and marine provinces **(Poster LTG2-9).** For stream classification research, continuous reach-level classification based on watershed characteristics using flow-accumulation techniques is planned, along with application of watershed classification to refine suspended-and-bedded-sediment (SABS) – response relationships for EPA Region 5, and possibly extension to additional regions, including arid and semi-arid **(Poster LTG2-10).** Estuarine classification efforts currently based on physical and hydrological properties will be tested with stressor and biological response data. The results of these tests along with the application of estuarine classification to the diagnosis of impairment and development of remediation strategies, will be used to provide a direction for modification and improvement.